

# Long Working Hours, Healthy Diets, and Cardiometabolic Health in US Workers

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# Background

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- WHO and ILO identified long working hours ( $\geq 55$  hours/week, LWH) as a significant occupational health risk, increasing the risk of stroke and ischemic heart disease (WHO & ILO, 2021)
- The National Institute for Occupational Safety and Health (NIOSH) and Occupational Safety and Health Administration (OSHA) recognize LWH as a critical worker safety concern, emphasizing the need for policies to mitigate fatigue-related health risks (NIOSH, 2021, OSHA)
- In general, working hours are generally less regulated, or fully unregulated outside Europe. In North America, working time regulations apply primarily to transport, and nuclear power plant operators (Anttila et al. 2021)

# Background

## WHO and ILO: “Long working hours is a significant occupational risk factor”

- A 42% increase in deaths from heart disease due to LWH between 2010 and 2016
- LWH contributed to 745,000 deaths of stroke and heart disease worldwide (2016)
- Stroke risk **↑ 35%** and ischemic heart disease mortality risk **↑ 17%** for those working  $\geq 55$  hrs/week vs. 35-40 hrs

Source: WHO, Duffy et al. 2020, Li, et al. Environ Int, 2020, Descatha, et al. Environ Int, 2020

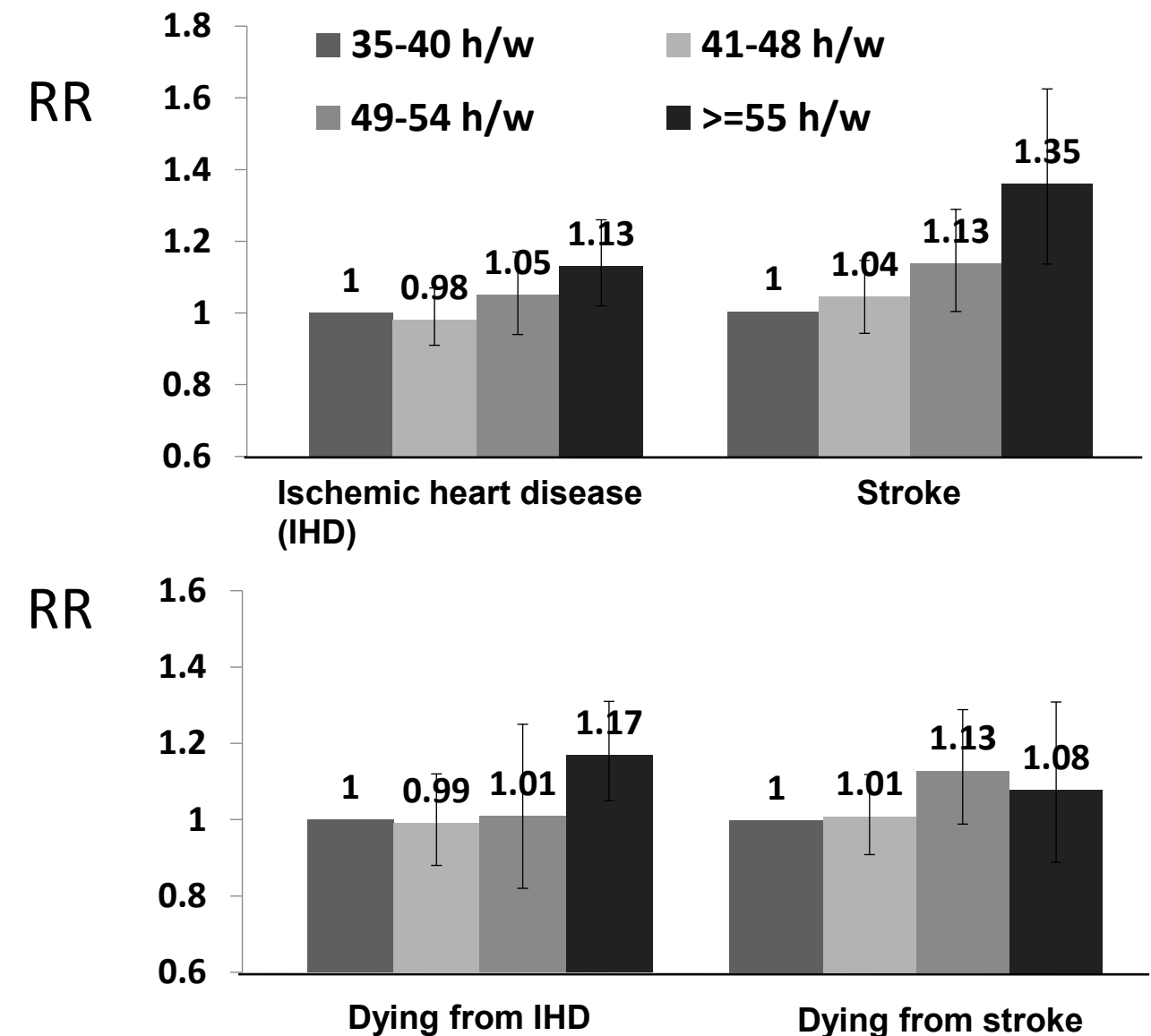
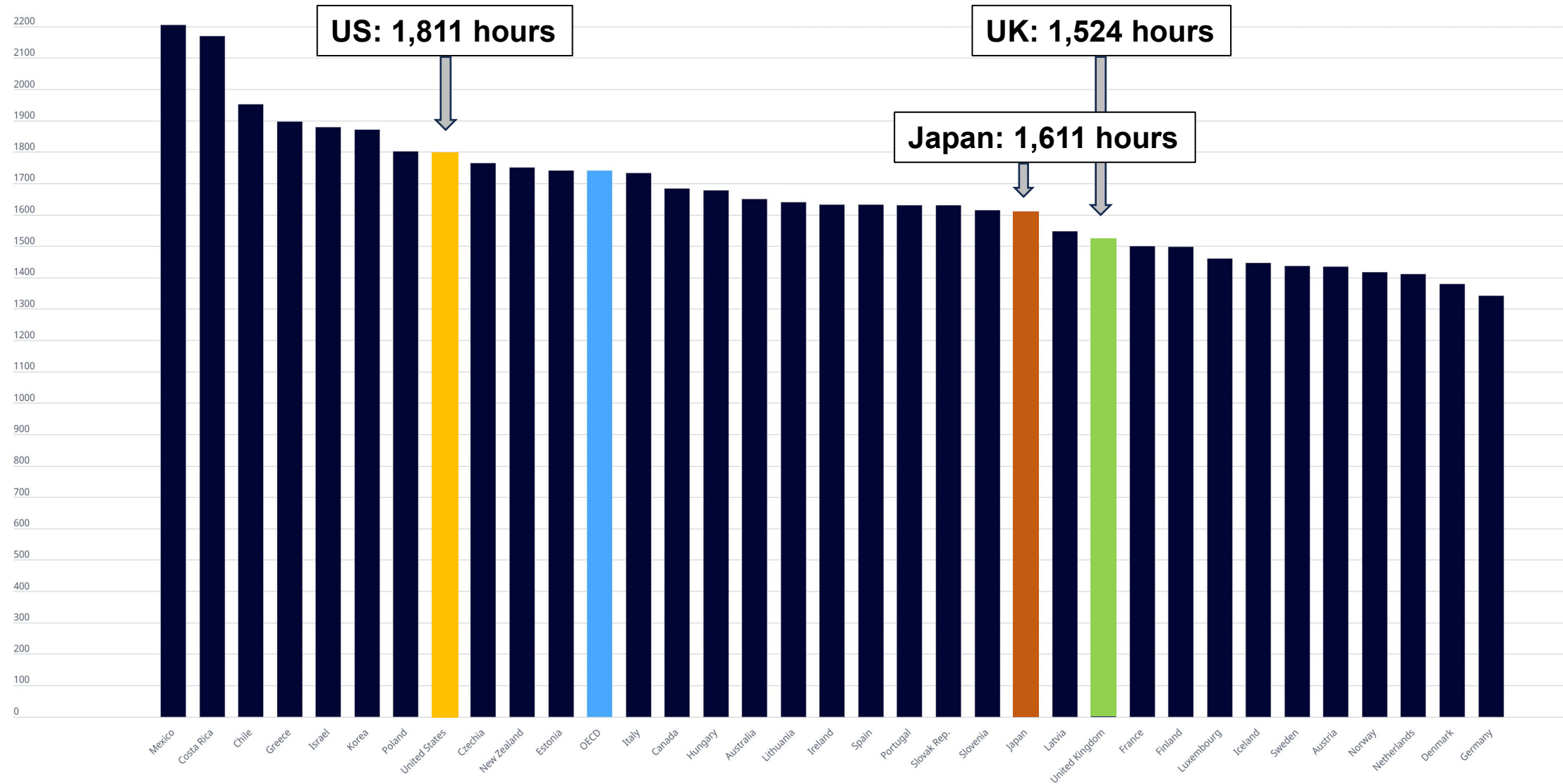


Figure adapted from Dr. Jian Li, 2024, “The WHO/ILO Joint Estimates of the Work-related Burden of Disease and Injury (long working hours and CVD)” at International Congress on Occupational Health Conference Presentation

# Background

## The global work clock: Who is putting in the hours?

Average hours  
per year per  
person

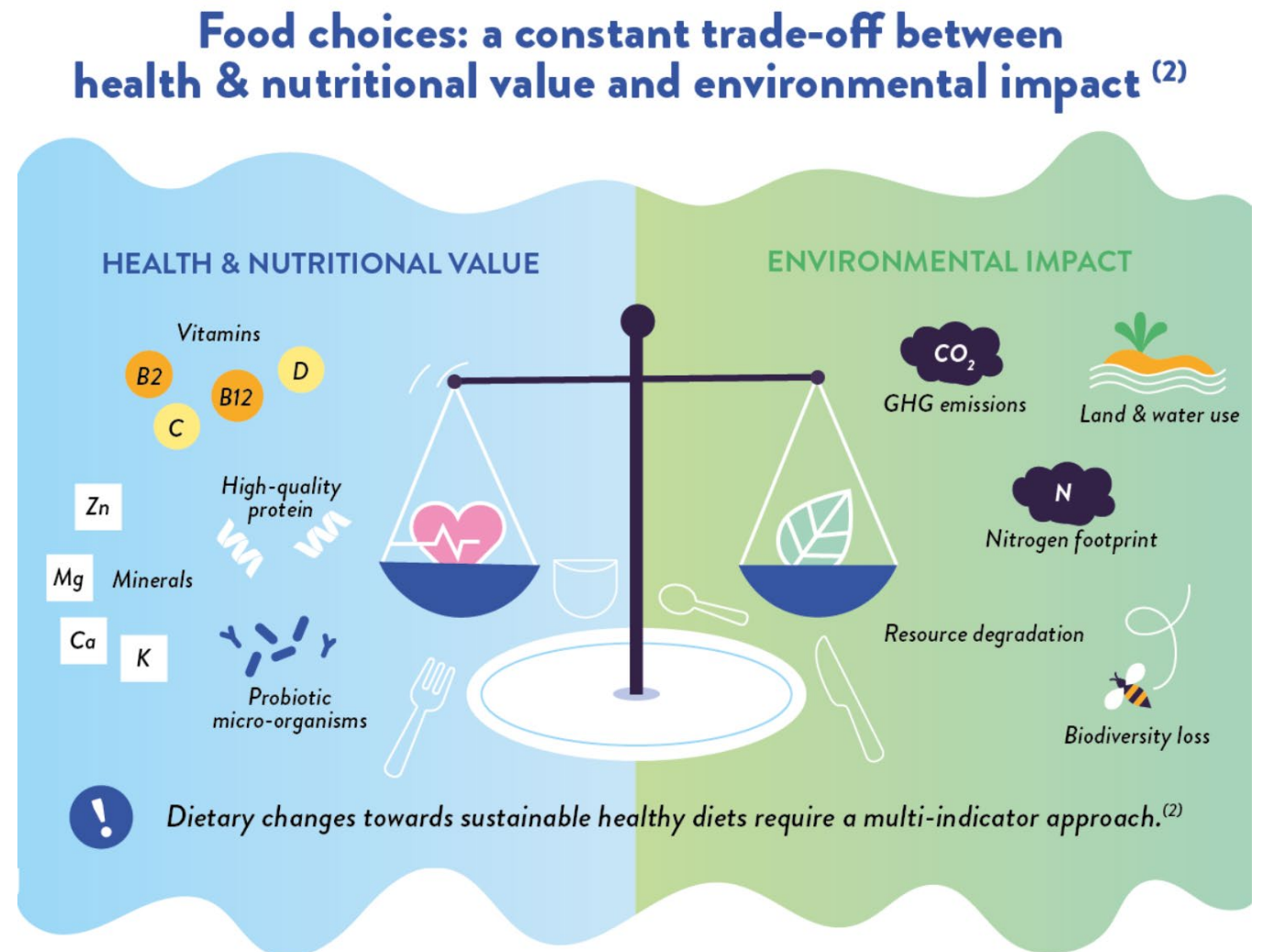


Source: Organization for Economic Co-operation and Development, 2023

# Background

## The Planetary Health Diet (EAT-Lancet Diet)









- Introduced by the EAT-Lancet Commission in 2019
- A universal, healthy reference diet to realign global food systems, improve environmental sustainability, and nurture human health
- Limits the intake of animal-based products and encourages plant-based foods
- Diets rich in plant products have lower environmental impacts

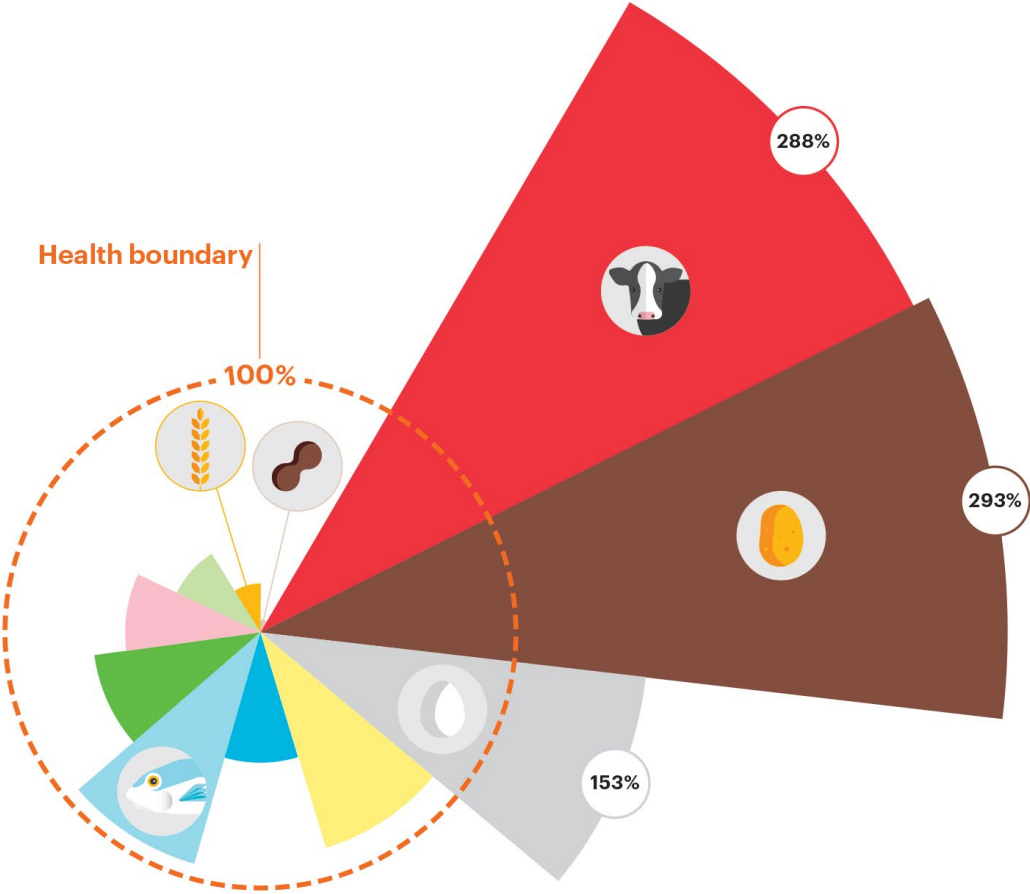


Source: The EAT-Lancet Commission, Berthy et al. 2022

# The Planetary Health Diet

## Planetary Health Diet

	Macronutrient intake grams per day (possible range)	Caloric intake kcal per day	
 Whole grains Rice, wheat, corn and other	232	811	
 Tubers or starchy vegetables Potatoes and cassava	50 (0–100)	39	
 Vegetables All vegetables	300 (200–600)	78	
 Fruits All fruits	200 (100–300)	126	
 Dairy foods Whole milk or equivalents	250 (0–500)	153	
 Protein sources	Beef, lamb and pork	14 (0–28)	30
	Chicken and other poultry	29 (0–58)	62
	Eggs	13 (0–25)	19
	Fish	28 (0–100)	40
	Legumes	75 (0–100)	284
	Nuts	50 (0–75)	291
 Added fats	Unsaturated oils	40 (20–80)	354
	Saturated oils	11.8 (0-11.8)	96
 Added sugars All sugars	31 (0–31)	120	

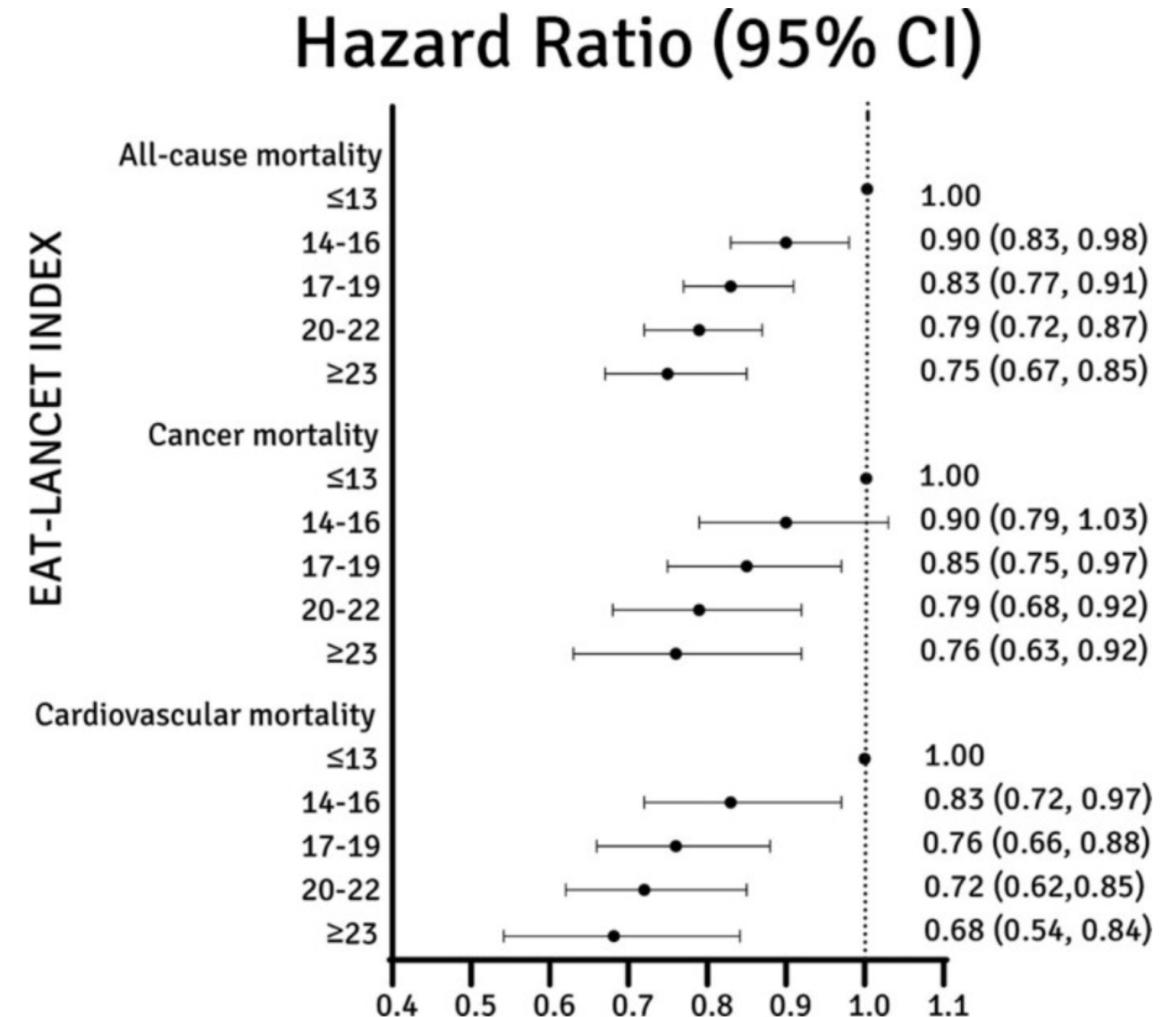


Source: Scaling up Nutrition, The EAT-Lancet Commissions

# Background

## EAT-Lancet Diet and Mortality

- Sweden cohort, mid-age, mean of 20 years of follow-up
- Adherence to EAT-Lancet diet (score  $\geq 23$ ): 25% lower all-cause mortality, 24% lower cancer mortality, and 32% lower cardiovascular mortality



Stubbendorff et al., Am J Clin Nutr 2022



# Gaps in Literature

- Few studies have investigated the association between LWH and cardiometabolic health and mortality in the US
- Lack of studies investigating EAT-Lancet diet in the US working population, and the joint effect with LWH is unknown

# Study Objectives

In a US working population:

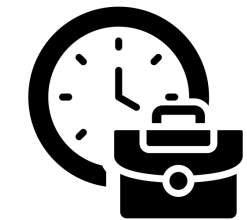
- The independent associations between LWH, poor diet quality, and cardiometabolic outcomes and mortality
- The joint effects of LWH and poor diet quality on cardiometabolic outcomes and mortality



# Study Aim 1



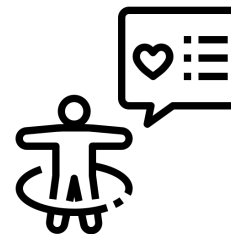
In US working population:



Long working  
hours (LWH)



Diet quality



Obesity,  
Diabetes,  
Hypertension,  
10-year CVD risk

**Aim1:** To examine the independent associations of LWH and diet quality on cardiometabolic outcomes

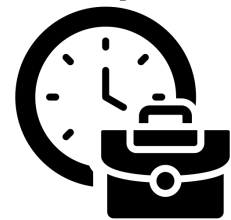
## Hypothesis

- LWH contributes to adverse cardiometabolic outcomes, e.g., higher risk of obesity, diabetes, hypertension, and 10-year CVD risk
- Low diet quality contributes to adverse cardiometabolic outcomes

# Study Aim 2



In US working population:



Long working  
hours (LWH)



Diet quality

Aim2: To examine the independent associations of LWH and diet quality on mortality outcomes

## Hypothesis

- LWH contributes to adverse mortality outcomes, e.g., higher risk of all-cause mortality, heart disease mortality, and CVD mortality
- Low diet quality contributes to adverse mortality outcomes



Mortality

# Study Aim 3

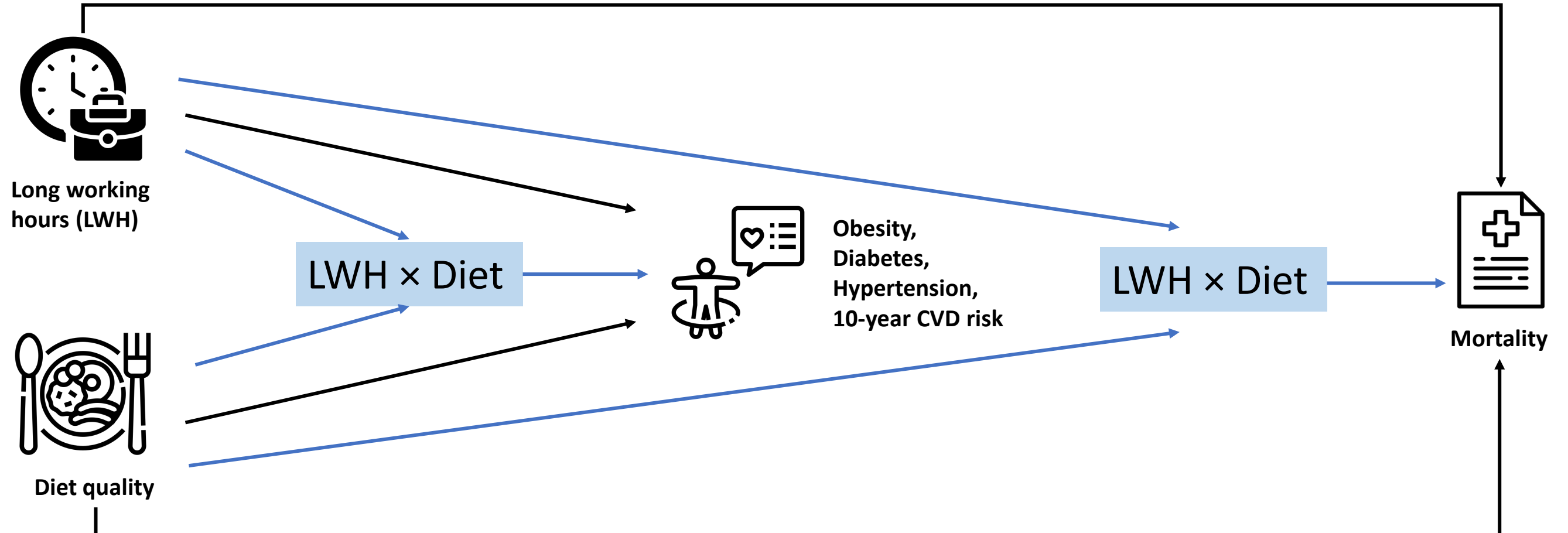


In US working population:

Aim3: To examine the joint associations of LWH and diet quality on cardiometabolic and mortality outcomes

Hypothesis

- LWH and poor diet quality will exacerbate the adverse effects



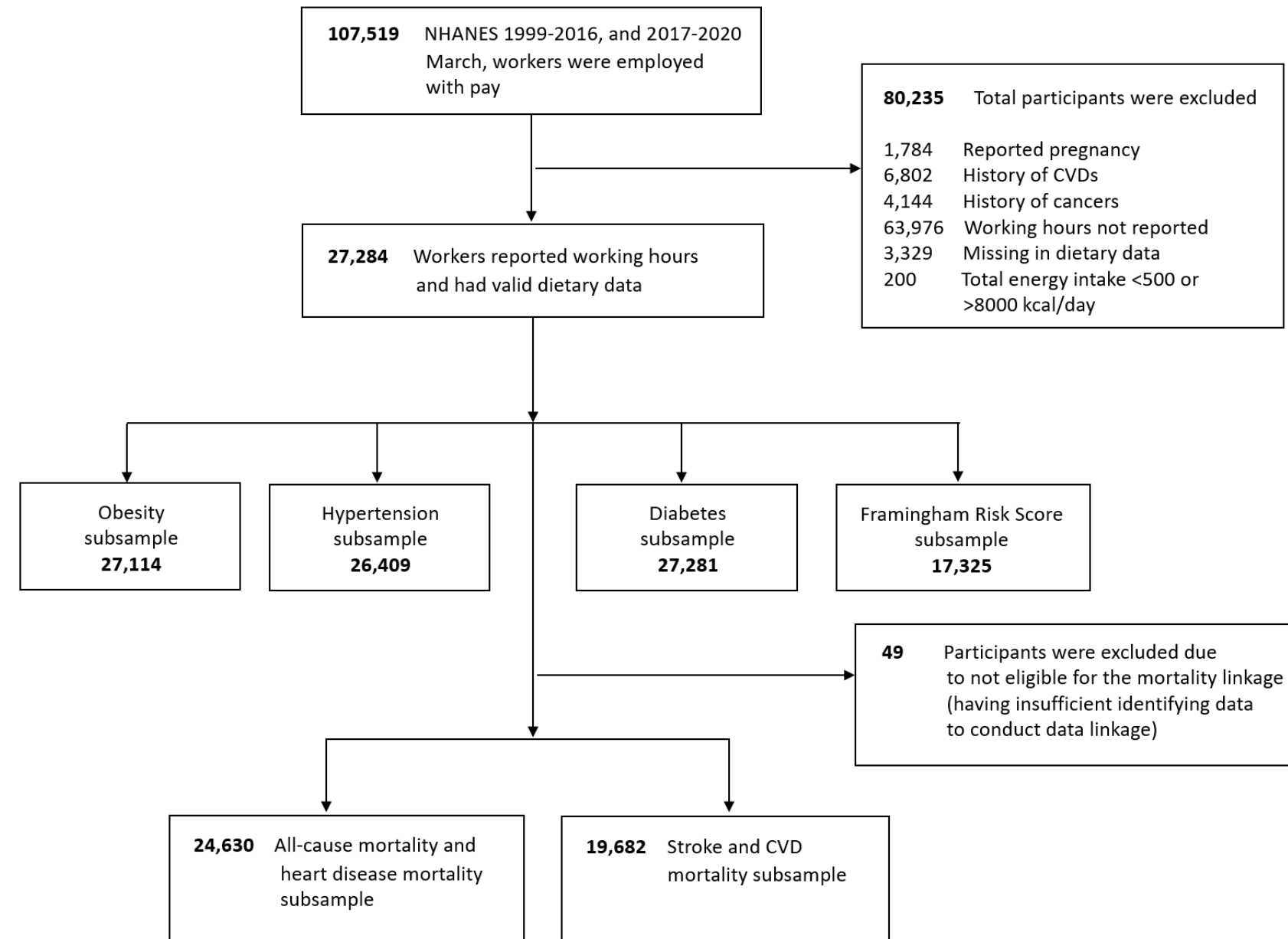
# Study Design



## Study and analytic population

- Cross-sectional analyses for cardiometabolic outcomes using data from 1999 through 2020 March
- Prospective follow-up for mortality

**Figure 1.** Sample selection flow diagram



# Methods

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## Exposures

- Long working hours (LWH):  $< 55$  vs.  $\geq 55$  hours/week
- Diet quality, measured by EAT-Lancet diet score (range 8 - 42 ): high vs. low (by the median score of 24)

## Outcomes

- Cardiometabolic outcomes: obesity, diabetes, hypertension, Framingham 10-year CVD risk score
- Mortality (by ICD-10): CVD (primary), all-cause and heart disease (secondary)

**Covariates:** Age, sex, race/ethnicity, family income, education level, smoking status, alcohol drinking, leisure time physical activity, total energy intake

## Statistical analysis (weighted analyses for the complex survey design)

- Cross-sectional associations: Multivariable logistic regression model
- Prospective associations: Multivariable Cox proportional hazards model
- Joint effects: relative excess risk due to interaction (RERI)

## Results: Baseline Characteristics and Follow-up Years

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- Mean age:  $39.5 \pm 0.2$  years
- Working 55 hours or more per week (LWH): 14%
  - More likely to be: males, married or living with partners, smokers, light-to-moderate drinkers, higher educated, and had higher income
- Mean EAT-Lancet diet score:  $24 \pm 0.06$  (range 8 – 24)
  - Workers with low diet score were more likely to be: younger, male, never married, smokers, heavy drinkers, less educated, less active and had lower income
- Combined groups
  - LWH + low diet score: 6.8%
  - LWH + high diet score: 8.1%
  - NWH + high diet score: 49.8%
  - NWH + low diet score: 35.3%
- Median (IQR) follow-up time: 10.3 (5.5-15.2) years for all-cause and heart disease mortality
- Median (IQR) follow-up time: 7.4 (3.6-11.5) years for CVD mortality

# Results: Cross-sectional Analysis of Cardiometabolic Outcomes

## Low adherence (score <24) to EAT-lancet diet:

- ↑ 31% higher odds of obesity
- ↑ 34% higher odds of diabetes
- ↑ 12% higher odds of hypertension

## LWH (≥ 55 hours/week):

- ↑ 20% higher odds of obesity

Fully adjusted model: adjusted for age, sex, race/ethnicity, education level, family income, smoking status, alcohol drinking, leisure time physical activity, total energy intake, and mutually adjusted for work hours or EAT-Lancet diet score.

**Table 2.** Independent cross-sectional associations between working hours, EAT-Lancet diet score, and cardiometabolic outcomes in US workers, the National Health and Nutrition Examination Survey 1999-2020 March.

	Long working hours		EAT-Lancet diet score	
	No (< 55 hours/week)	Yes (≥ 55 hours/week)	High (≥ 24)	Low (< 24)
	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
<b>Obesity (N=27,114)</b>				
No. cases / Total number	7762 / 23529	1348 / 3585	4970 / 15821	4140 / 11293
Crude model	1.00	1.20 (1.08, 1.34)	1.00	1.29 (1.20, 1.39)
Fully adjusted model	1.00	1.20 (1.07, 1.34)	1.00	1.31 (1.21, 1.42)
<b>Diabetes (N=27,281)</b>				
No. cases / Total number	2127 / 23672	367 / 3609	1484 / 15924	1010 / 11357
Crude model	1.00	1.12 (0.94, 1.34)	1.00	1.17 (1.04, 1.32)
Fully adjusted model	1.00	1.08 (0.90, 1.30)	1.00	1.34 (1.17, 1.53)
<b>Hypertension (N=26,409)</b>				
No. cases / Total number	7219 / 22922	1261 / 3487	4865 / 15403	3615 / 11006
Crude model	1.00	1.20 (1.08, 1.34)	1.00	1.07 (0.99, 1.15)
Fully adjusted model	1.00	1.01 (0.90, 1.13)	1.00	1.12 (1.03, 1.20)
<b>Framingham 10-year CVD risk: High (N=17,325)</b>				
No. cases / Total number	1651 / 14687	275 / 2638	1103 / 10520	823 / 6805
Crude model	1.00	0.99 (0.81, 1.21)	1.00	1.20 (1.03, 1.40)
Fully adjusted model <sup>a</sup>	1.00	0.98 (0.80, 1.19)	1.00	1.16 (0.99, 1.36)



# Results: Prospective Analysis of Mortality

## Low adherence (score <24) to EAT-lancet diet:

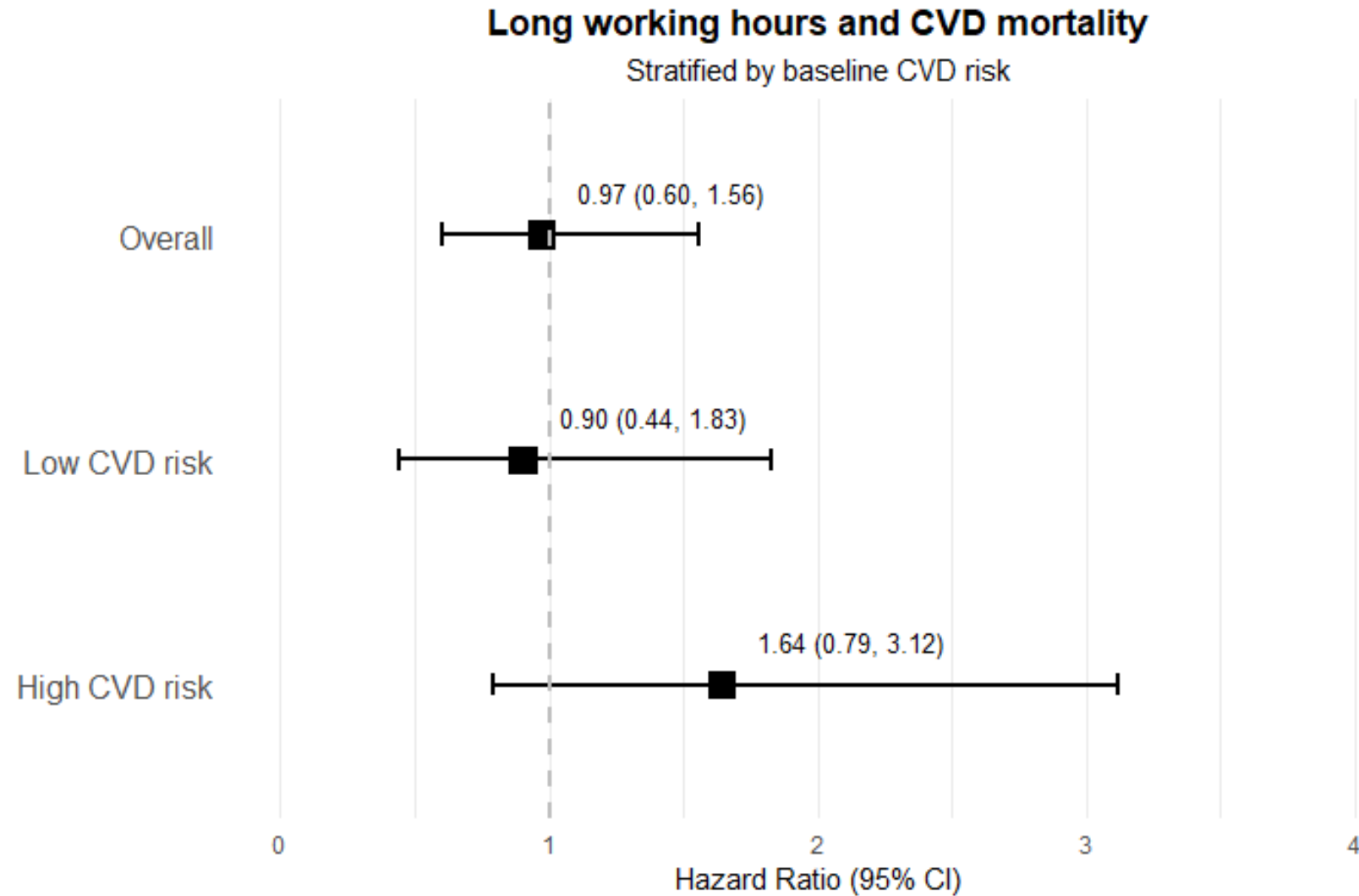
- ↑ 45% higher risk of CVD mortality
- ↑ 25% higher risk of all-cause mortality
- ↑ 62% higher risk of heart disease mortality

Fully adjusted model: adjusted for age, sex, race/ethnicity, education level, family income, smoking status, alcohol drinking, leisure time physical activity, total energy intake, and working hours.

**Table 3.** Independent associations between long working hours, EAT-Lancet diet and mortality

	Long working hours		EAT-Lancet diet score	
	No (< 55 hours/week)	Yes (≥ 55 hours/week)	High (≥ 24)	Low (< 24)
	HR (95%CI)	HR (95%CI)	HR (95%CI)	HR (95%CI)
<b>CVD mortality</b>				
No. CVD death/Total	168 / 10871	28 / 2008	87 / 6716	107 / 6171
Mortality (1/1000)	15.5	13.9	13.0	17.3
Crude model	1.00	1.02 (0.63, 1.63)	1.00	1.34 (0.91, 1.97)
Fully adjusted model	1.00	0.97 (0.60, 1.56)	1.00	1.45 (0.96, 2.19)
<b>All-cause mortality</b>				
No. All-cause death/Total	930 / 21244	130 / 3386	464 / 12084	596 / 12546
Mortality (1/1000)	43.8	38.4	38.4	47.5
Crude model	1.00	0.98 (0.74, 1.30)	1.00	1.23 (1.03, 1.47)
Fully adjusted model	1.00	0.93 (0.69, 1.25)	1.00	1.25 (1.05, 1.50)
<b>Heart disease mortality</b>				
No. Heart disease death/Total	192 / 21244	29 / 3386	90 / 12084	131 / 12546
Mortality (1/1000)	9.0	8.5	7.4	10.4
Crude model	1.00	0.93 (0.56, 1.56)	1.00	1.48 (0.92, 2.39)
Fully adjusted model	1.00	0.86 (0.51, 1.46)	1.00	1.62 (0.98, 2.69)

# Results: Prospective Analysis of Mortality

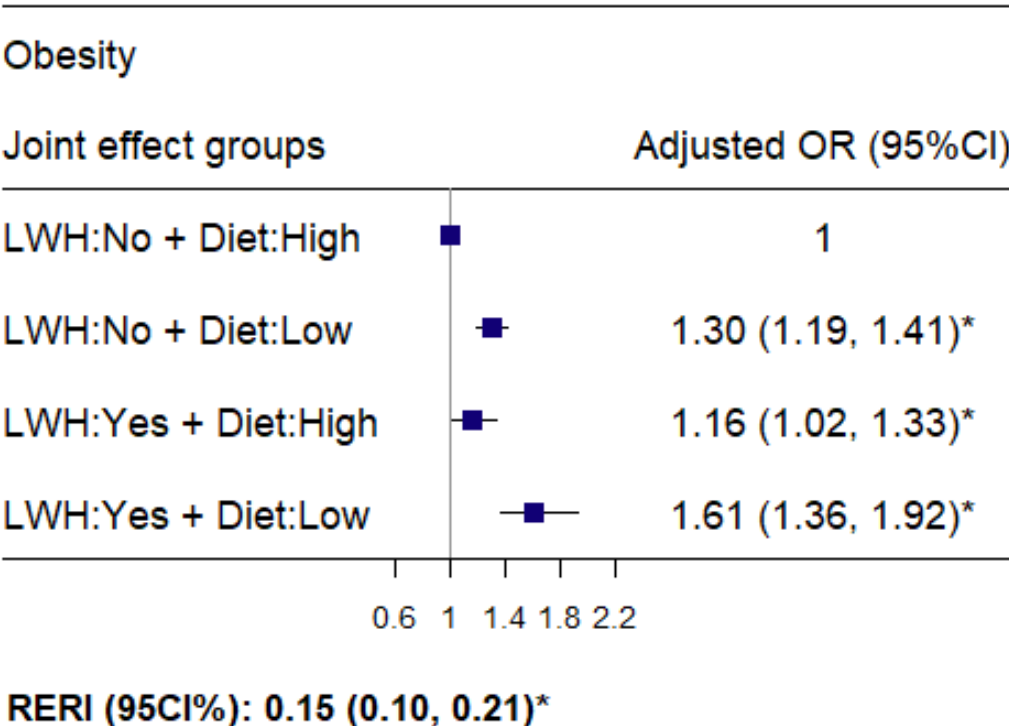


High CVD risk: Framingham score  $\geq 20\%$ .

Hazard ratio was adjusted for race/ethnicity, education level, family income, alcohol drinking, leisure time physical activity, total energy intake, and EAT-Lancet diet score.

# Results: Joint effects

- LWH and low diet score were jointly associated with 61% higher odds of obesity and 73% higher CVD mortality risk
- Additive interaction between LWH and low diet score



Abbreviation: LWH: No, working hours < 55 h/wk; LWH: Yes, working hours ≥ 55 h/wk; Diet: High, EAT-Lancet diet score ≥ 24; Diet: Low, EAT-Lancet diet score < 24;

# Discussion

## Main findings

- **LWH** ( $\geq 55$  hours/week) was associated with a higher odds of obesity in all participants and substantially increased risk of CVD mortality among workers with high baseline CVD risk, independent of diet quality
- **Low adherence of EAT-Lancet diet** was linked to higher odds of obesity, diabetes, and hypertension; also, higher risks of mortality from CVD, heart disease, and all-causes, independent of working hours
- Jointly: **LWH** + **low adherence of EAT-Lancet diet** produced an additive effect on obesity and CVD mortality

## Strengths

- National representative sample of the US workers
- Relatively large sample size (>20,000)

## Limitations

- Single-point measurements of working hours and diet
- Reverse causation in cross-sectional analyses
- No information on effort-reward mechanism
- Residual confounding

# Summary

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- **LWH** may increase the risk of obesity and CVD mortality (only with high CVD risk) among US workers
- **Poor diet quality** may increase the risk of adverse cardiometabolic outcomes and CVD mortality among US workers
- The combination of **LWH** and **poor diet quality** may have joint effects and exacerbate the risk of adverse cardiometabolic health in US workers

# Public Health Implication

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- Pioneering study in assessing the relationship between EAT-Lancet diet and cardiometabolic outcomes and CVD mortality in the US workforce
- Workers exposed to LWH and poor diet represent a critical preventable burden—a prime opportunity for workplace interventions to curb obesity, hypertension, and mortality
- Individual actions like a healthy diet are critical, especially when job re-design at an organizational level may take longer to implement

# Acknowledgment

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**Co-authors:** Dr. Liwei Chen, Dr. Jian Li, Dr. Onyebuchi A. Arah, Dr. Tong Xia, Xuyuehe Ren

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# Sensitivity Analyses

## Sensitivity Analysis 1:

Exclude individuals reporting working hours < 35 hrs/week

- May be part-time job workers
- Or in weak health conditions

*Results showed neglectable changes*

	Long working hours		EAT-Lancet diet score	
	No (< 55 hours/week)	Yes (≥ 55 hours/week)	High (≥ 24)	Low (< 24)
	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
<b>Obesity</b>				
Primary analysis	1.00	1.20 (1.07, 1.34)	1.00	1.31 (1.21, 1.42)
Sensitivity analysis 1	1.00	1.15 (1.03, 1.29)	1.00	1.33 (1.21, 1.45)
<b>Diabetes</b>				
Primary analysis	1.00	1.05 (0.85, 1.30)	1.00	1.34 (1.17, 1.53)
Sensitivity analysis 1	1.00	1.05 (0.86, 1.27)	1.00	1.31 (1.13, 1.52)
<b>Hypertension</b>				
Primary analysis	1.00	1.00 (0.88, 1.13)	1.00	1.12 (1.03, 1.20)
Sensitivity analysis 1	1.00	0.99 (0.88, 1.11)	1.00	1.11 (1.01, 1.21)
<b>Framingham 10-year CVD risk: High</b>				
Primary analysis	1.00	0.98 (0.80, 1.19)	1.00	1.16 (0.99, 1.36)
Sensitivity analysis 1	1.00	1.10 (0.90, 1.34)	1.00	1.13 (0.94, 1.36)
	HR (95%CI)	HR (95%CI)	HR (95%CI)	HR (95%CI)
<b>CVD mortality</b>				
Primary analysis	1.00	0.97 (0.60, 1.56)	1.00	1.45 (0.96, 2.19)
Sensitivity analysis 1	1.00	0.96 (0.58, 1.57)	1.00	1.50 (0.88, 2.55)
<b>All-cause mortality</b>				
Primary analysis	1.00	0.93 (0.69, 1.25)	1.00	1.25 (1.05, 1.50)
Sensitivity analysis 1	1.00	1.00 (0.73, 1.37)	1.00	1.18 (0.96, 1.46)
<b>Heart disease mortality</b>				
Primary analysis	1.00	0.93 (0.54, 1.58)	1.00	1.57 (0.84, 2.91)
Sensitivity analysis 1	1.00	0.93 (0.54, 1.58)	1.00	1.57 (0.84, 2.91)

Model adjusted for age, sex, race/ethnicity, education level, family income, smoking status, alcohol drinking, leisure time physical activity, and total energy intake. Diet scores were further adjusted in models assessing long working hours, and working hours were further adjusted in models when assessing diet scores.

# Sensitivity Analyses

## Sensitivity Analysis 2:

Occupation types adjustment (i.e. white-collar and professional, white-collar semi-routine, blue-collar semi-routine, blue-collar high skill)

- Working hours may vary across occupation types
- Differences in salaried roles (e.g., pay by hours versus flexible but “always on”) could affect health outcomes due to stress, fatigue, etc. )

*Results showed neglectable changes*

	Long working hours		EAT-Lancet diet score	
	No (< 55 hours/week)	Yes (≥ 55 hours/week)	High (≥ 24)	Low (< 24)
	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
Obesity				
Primary analysis	1.00	1.20 (1.07, 1.34)	1.00	1.31 (1.21, 1.42)
Sensitivity analysis 2	1.00	1.25 (1.10, 1.42)	1.00	1.33 (1.17, 1.53)
Diabetes				
Primary analysis	1.00	1.05 (0.85, 1.30)	1.00	1.34 (1.17, 1.53)
Sensitivity analysis 2	1.00	1.05 (0.85, 1.30)	1.00	1.22 (0.97, 1.55)
Hypertension				
Primary analysis	1.00	1.00 (0.88, 1.13)	1.00	1.12 (1.03, 1.20)
Sensitivity analysis 2	1.00	1.00 (0.88, 1.13)	1.00	1.17 (1.04, 1.30)
Framingham 10-year CVD risk: High				
Primary analysis	1.00	0.98 (0.80, 1.19)	1.00	1.16 (0.99, 1.36)
Sensitivity analysis 2	1.00	0.90 (0.67, 1.18)	1.00	1.16 (0.94, 1.38)
	HR (95%CI)	HR (95%CI)	HR (95%CI)	HR (95%CI)
CVD mortality				
Primary analysis	1.00	0.97 (0.60, 1.56)	1.00	1.45 (0.96, 2.19)
Sensitivity analysis 2	1.00	0.96 (0.60, 1.54)	1.00	1.44 (0.95, 2.18)
All-cause mortality				
Primary analysis	1.00	0.93 (0.69, 1.25)	1.00	1.25 (1.05, 1.50)
Sensitivity analysis 2	1.00	0.96 (0.71, 1.29)	1.00	1.22 (1.02, 1.46)
Heart disease mortality				
Primary analysis	1.00	0.86 (0.51, 1.46)	1.00	1.62 (0.98, 2.69)
Sensitivity analysis 2	1.00	0.97 (0.58, 1.61)	1.00	1.51 (0.90, 2.50)

Model adjusted for age, sex, race/ethnicity, education level, family income, smoking status, alcohol drinking, leisure time physical activity, and total energy intake. Diet scores were further adjusted in models assessing long working hours, and working hours were further adjusted in models when assessing diet scores.

# Sensitivity Analyses

## Sensitivity Analysis 3:

### Shift status adjustment

- Potential confounder or effect modifier
- Through different mechanism (e.g., disrupt circadian rhythm, metabolic dysregulation, etc.)

*Results on cardiometabolic outcomes showed neglectable changes*

*For mortality outcomes, point estimates became more positive after accounting for shift work (further reinforcing our initial hypothesis that LWH increase mortality risk!)*

	Long working hours		EAT-Lancet diet score	
	No (< 55 hours/week)	Yes (≥ 55 hours/week)	High (≥ 24)	Low (< 24)
	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
<b>Obesity</b>				
Primary analysis	1.00	1.20 (1.07, 1.34)	1.00	1.31 (1.21, 1.42)
Sensitivity analysis 3	1.00	1.21 (0.97, 1.52)	1.00	-
<b>Diabetes</b>				
Primary analysis	1.00	1.05 (0.85, 1.30)	1.00	1.34 (1.17, 1.53)
Sensitivity analysis 3	1.00	1.03 (0.77, 1.39)	1.00	-
<b>Hypertension</b>				
Primary analysis	1.00	1.00 (0.88, 1.13)	1.00	1.12 (1.03, 1.20)
Sensitivity analysis 3	1.00	1.01 (0.88, 1.14)	1.00	-
<b>Framingham 10-year CVD risk: High</b>				
Primary analysis	1.00	0.98 (0.80, 1.19)	1.00	1.16 (0.99, 1.36)
Sensitivity analysis 3	1.00	0.97 (0.61, 1.57)	1.00	-
	HR (95%CI)	HR (95%CI)	HR (95%CI)	HR (95%CI)
<b>CVD mortality</b>				
Primary analysis	1.00	0.97 (0.60, 1.56)	1.00	1.45 (0.96, 2.19)
Sensitivity analysis 3	1.00	1.72 (0.77, 3.84)	1.00	-
<b>All-cause mortality</b>				
Primary analysis	1.00	0.93 (0.69, 1.25)	1.00	1.25 (1.05, 1.50)
Sensitivity analysis 3	1.00	1.40 (0.82, 2.40)	1.00	-
<b>Heart disease mortality</b>				
Primary analysis	1.00	0.86 (0.51, 1.46)	1.00	1.62 (0.98, 2.69)
Sensitivity analysis 3	1.00	1.41 (0.55, 3.63)	1.00	-

Model adjusted for age, sex, race/ethnicity, education level, family income, smoking status, alcohol drinking, leisure time physical activity, and total energy intake. Diet scores were further adjusted in models assessing long working hours, and working hours were further adjusted in models when assessing diet scores.

Work schedule status (any shift work versus non-shift work) was only surveyed in the NHANES cycles from the year 2005 to 2010

# Sensitivity Analyses

## Sensitivity Analysis 4:

Different BMI thresholds for obesity accounting for race/ethnic groups – applying 27.5 kg/m2 to workers self-reported as “Non-Hispanic Asian”

- The WHO panel recommended a lower BMI cutoff for obesity in Asian descendent people of  $\geq 27.5$  kg/m2 instead of the standard  $\geq 30.0$  kg/m2

Only 0.4% increase in the prevalence of obesity

Results on showed neglectable changes

Obesity Prevalence by standard versus race/ethnic specific BMI cutoffs

Obesity (N=27114)	Standard cutoff		Ethnic specific cutoff	
	Count (%)		Count (%)	
No	18004 (66.5)		17801 (66.1)	
Yes	9110 (33.5)		93213 (33.9)	

	Long working hours		EAT-Lancet diet score	
	No (< 55 hours/week)	Yes ( $\geq$ 55 hours/week)	High ( $\geq$ 24)	Low (< 24)
	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
Obesity				
Primary analysis	1.00	1.20 (1.07, 1.34)	1.00	1.31 (1.21, 1.42)
Race/ethnic specific BMI cutoffs	1.00	1.19 (1.06, 1.33)	1.00	1.31 (1.21, 1.42)